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Ohno et al.

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(45) **Date of Patent: Sep. 15, 2015**

(54) **MAGNETORESISTANCE EFFECT ELEMENT AND MAGNETIC MEMORY**

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H01L 43/08 (2006.01)
(Continued)

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CPC H01L 43/02; H01L 43/08; H01L 43/085; G11C 11/14–11/16; G11C 11/161
See application file for complete search history.

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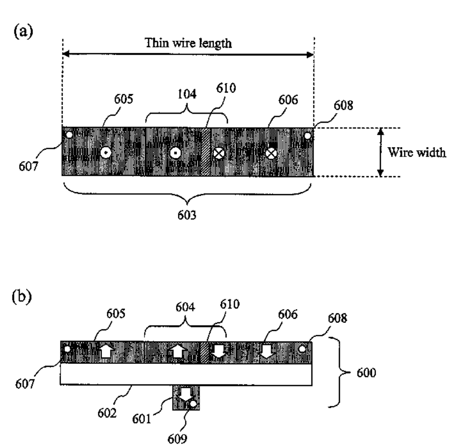
Primary Examiner — Allison P Bernstein
(74) *Attorney, Agent, or Firm* — Baker Botts L.L.P.

(57) **ABSTRACT**

Provided are a magnetoresistance effect element with a stable magnetization direction perpendicular to film plane and a controlled magnetoresistance ratio, in which writing can be performed by magnetic domain wall motion, and a magnetic memory including the magnetoresistance effect element. The magnetoresistance ratio is controlled by forming a ferromagnetic layer of the magnetoresistance effect element from a ferromagnetic material including at least one type of 3d transition metal or a Heusler alloy. The magnetization direction is changed from a direction in the film plane to a direction perpendicular to the film plane by controlling the film thickness of the ferromagnetic layer on an atomic layer level.

19 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

H01L 43/02	(2006.01)
G11C 11/14	(2006.01)
H01L 27/22	(2006.01)

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FIG. 1
PRIOR ART

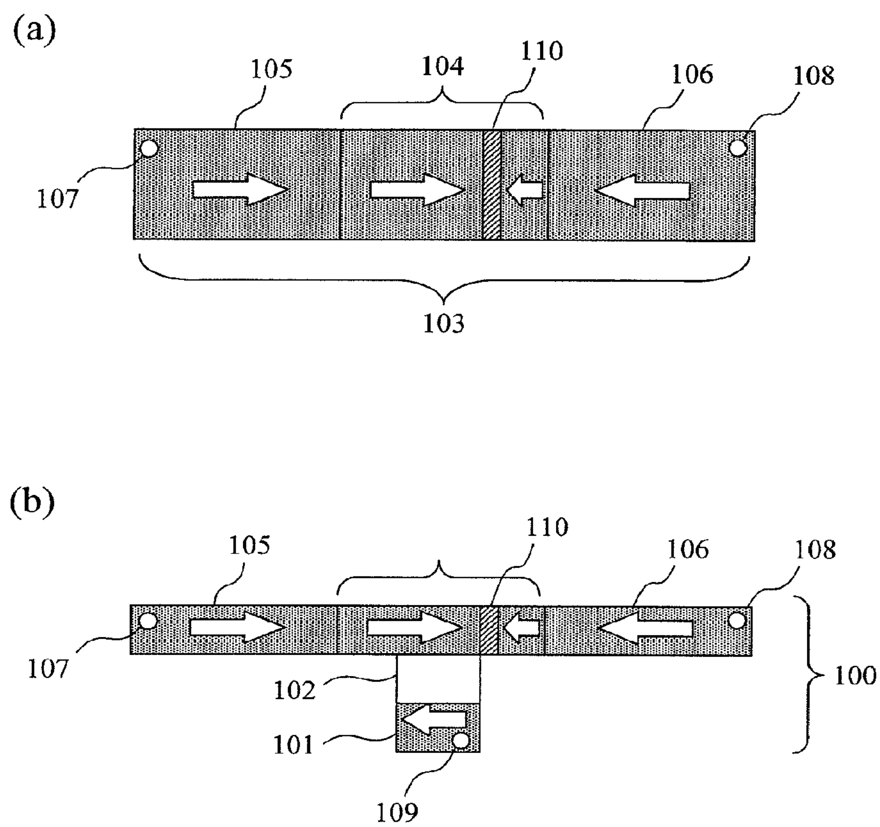


FIG. 2

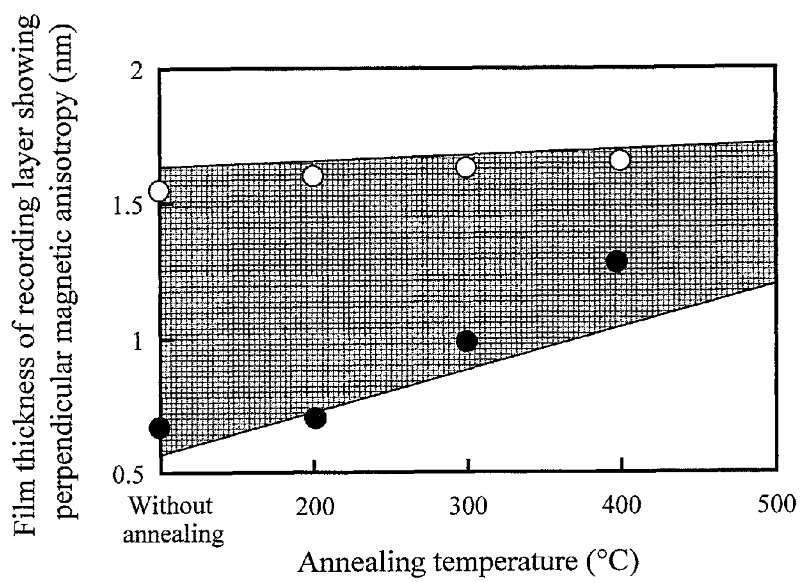

Film thickness of recording layer showing perpendicular magnetic anisotropy (nm)
2
1.5
1
0.5
Without annealing
200
300
400
500
Annealing temperature (°C)

FIG. 3

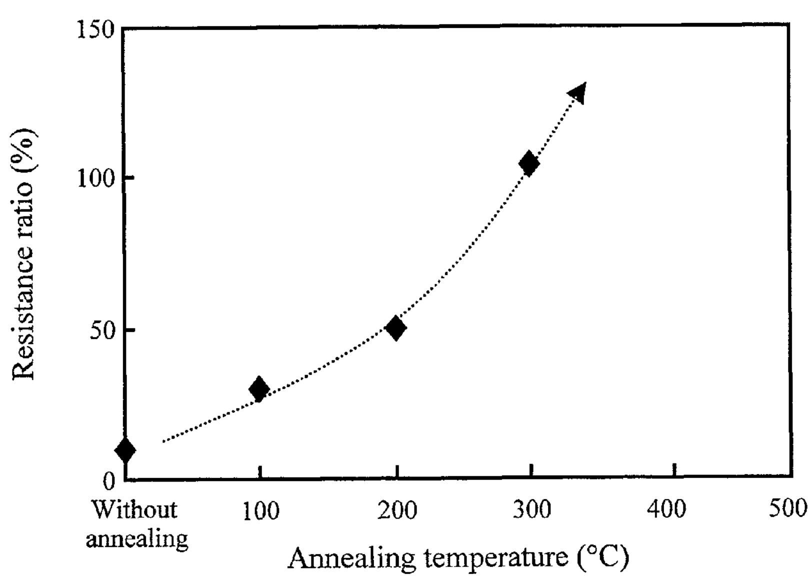

Resistance ratio (%)
150
100
50
0
Without annealing
100
200
300
400
500
Annealing temperature (°C)

FIG. 4

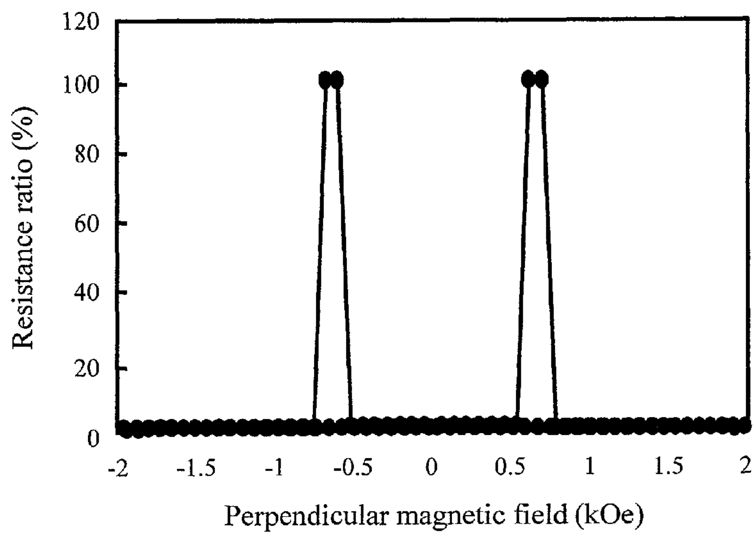

120
100
80
60
40
20
0
Resistance ratio (%)
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Perpendicular magnetic field (kOe)

FIG. 5

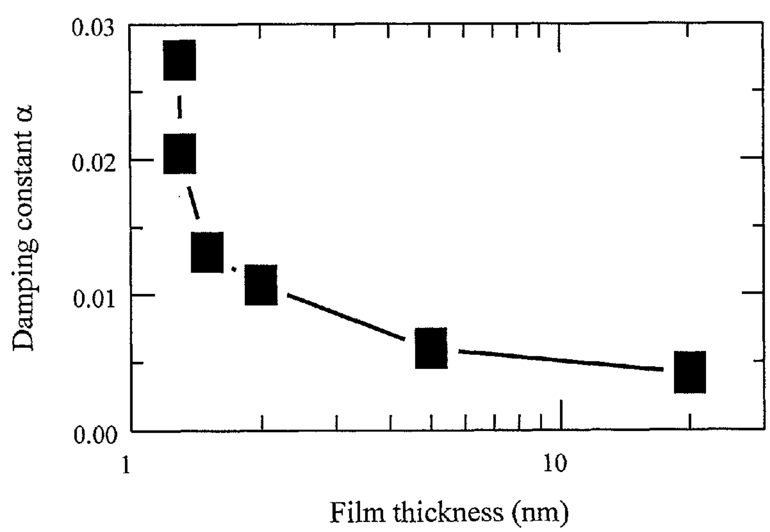

0.03
0.02
0.01
0.00
Damping constant α
1
10
Film thickness (nm)

FIG. 6

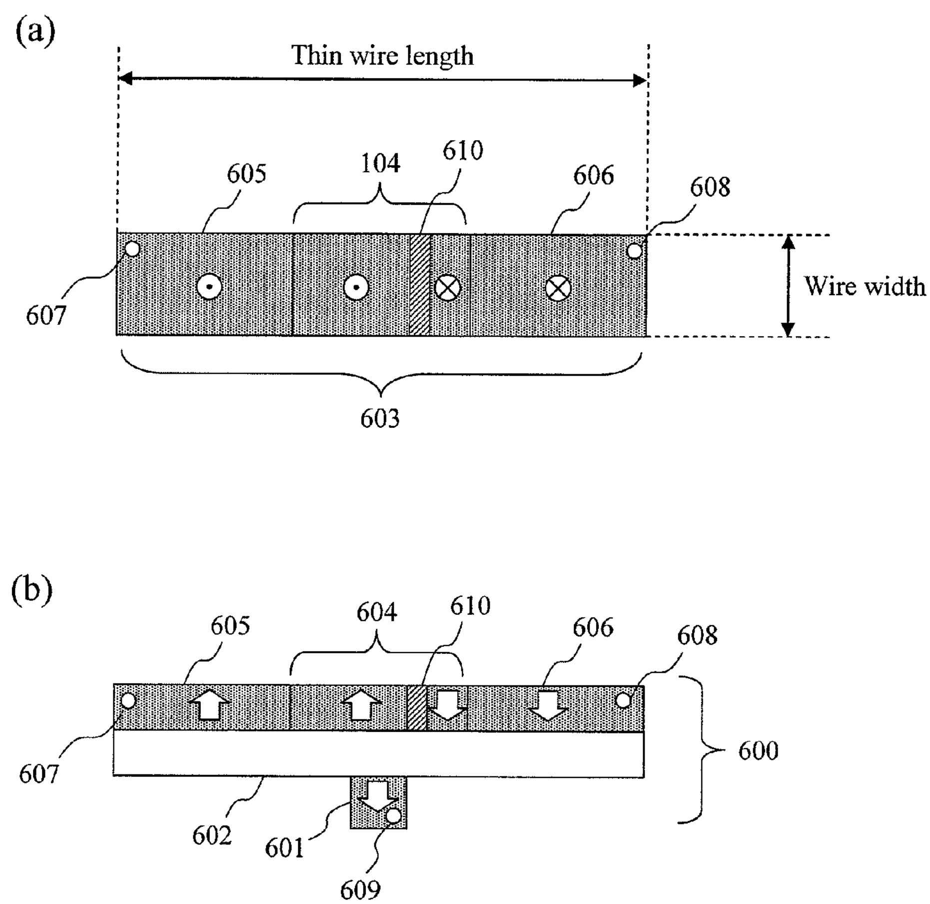

(a)
Thin wire length
605
104
610
606
608
Wire width
607
603
(b)
605
604
610
606
608
607
600
602
601
609

FIG. 7

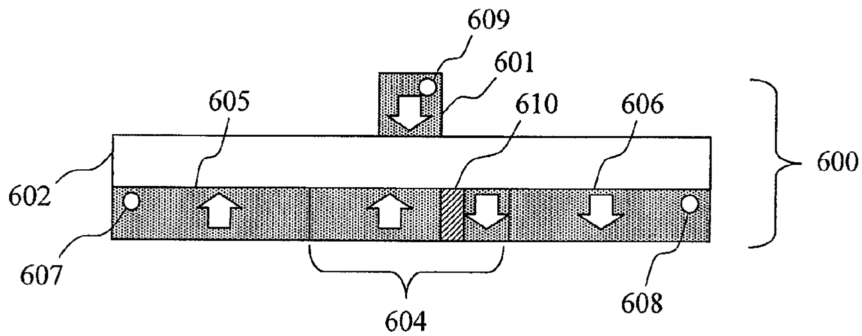


FIG. 8

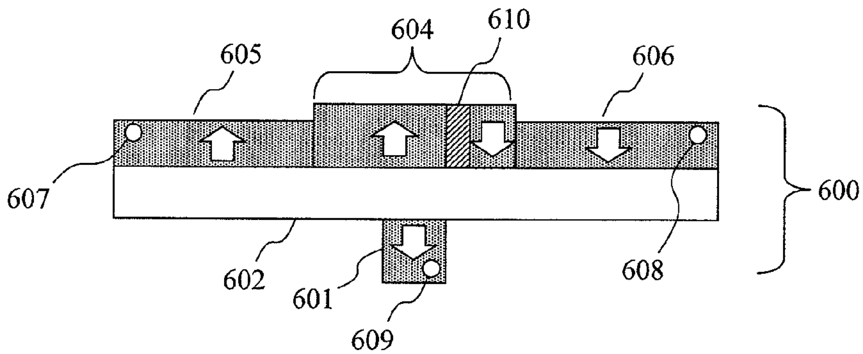


FIG. 9

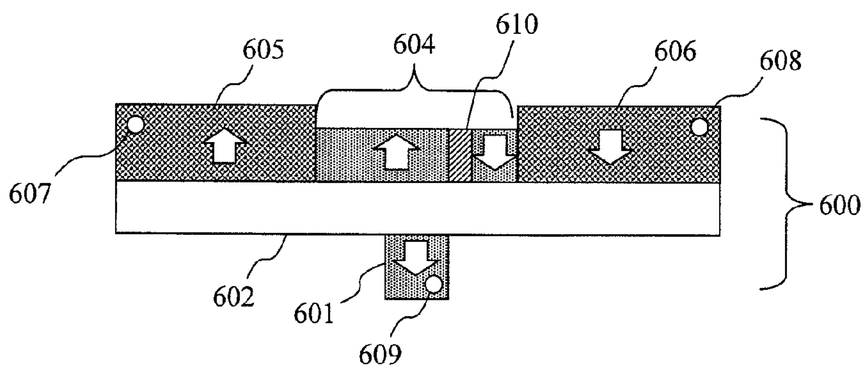


FIG. 10

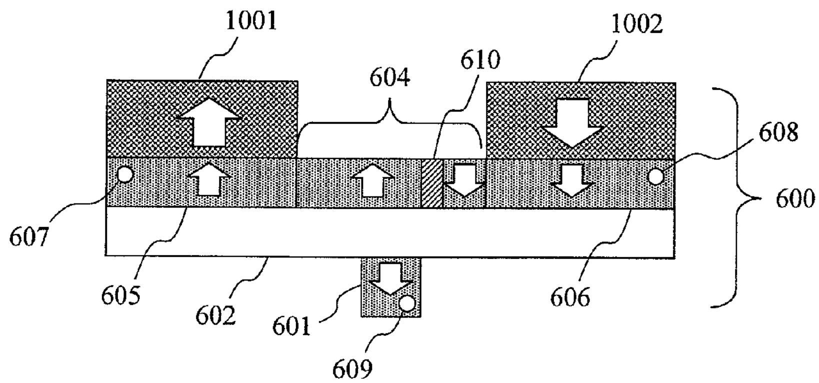
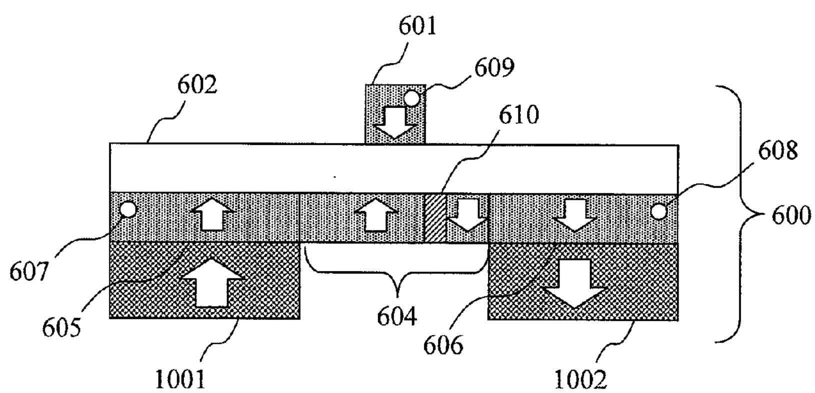

1001
1002
604
610
608
600
607
605
602
601
609
606

FIG. 11


601
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1001
1002

FIG. 12

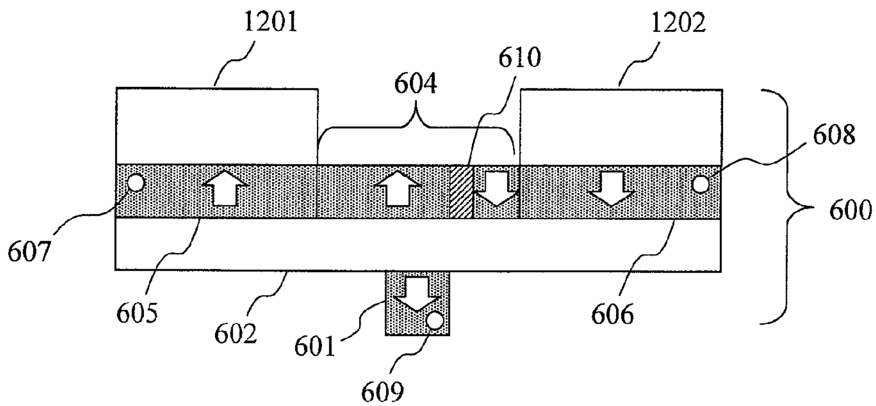
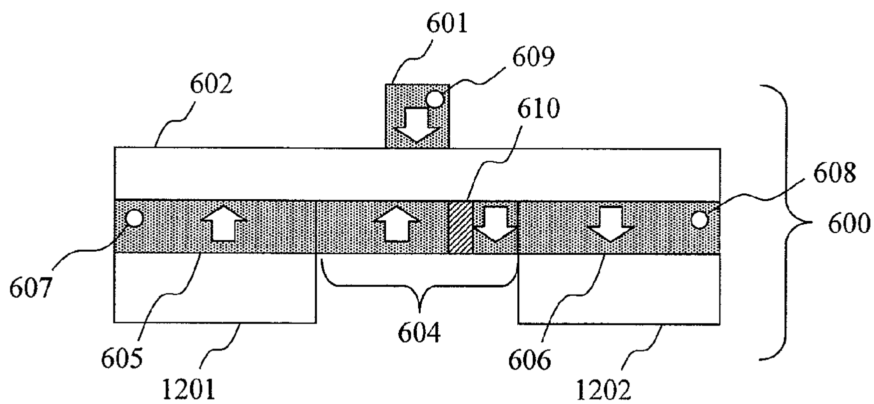

1201
1202
604
610
608
600
607
605
602
601
609
606

FIG. 13


601
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605
1201
604
606
1202

FIG. 14

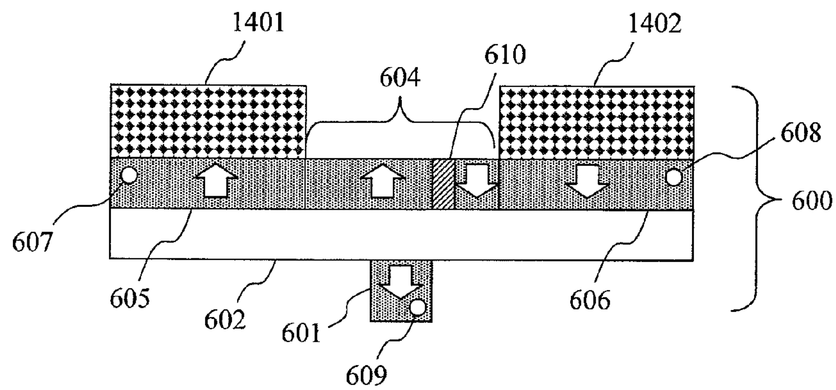

1401
1402
610
604
608
600
607
605
602
601
609
606

FIG. 15

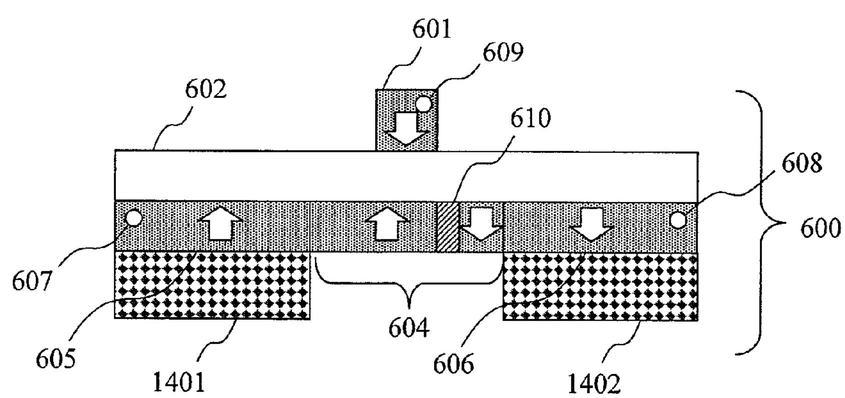
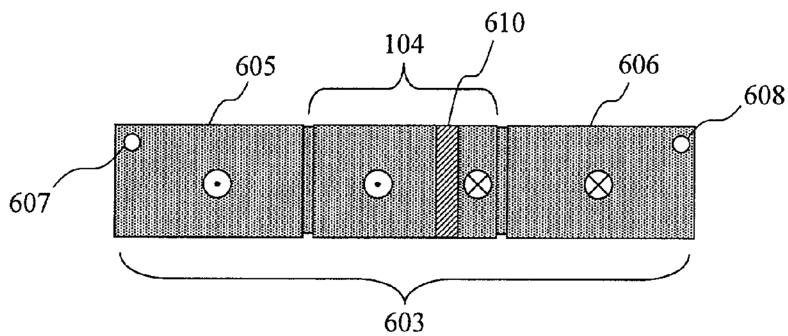
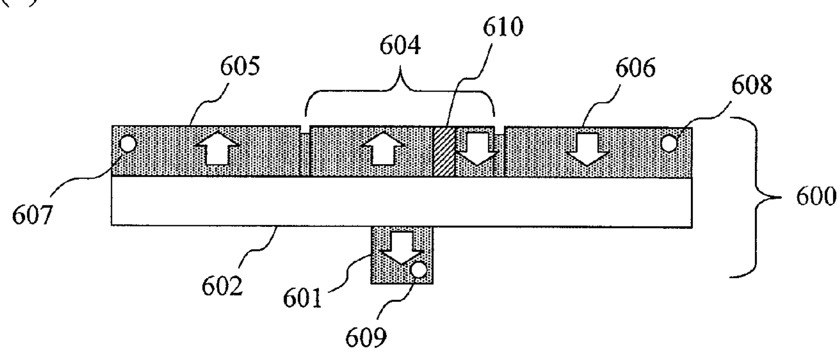

601
609
602
610
608
600
607
605
1401
604
606
1402

FIG. 16

(a)


605
104
610
606
608
607
603

(b)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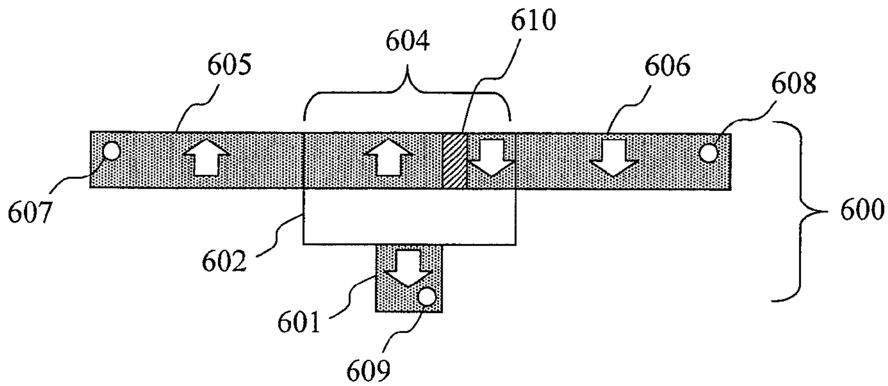
601
609

FIG. 17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610
605
606
608
607
600
602
601
609

FIG. 18

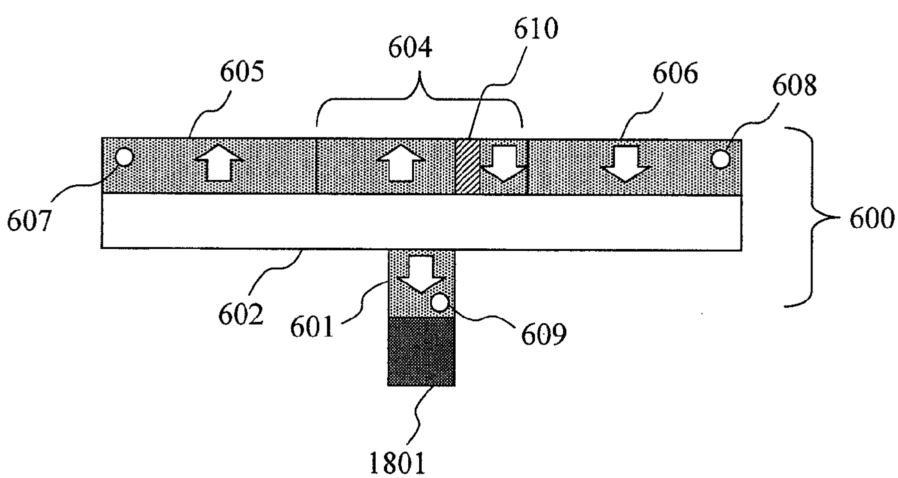
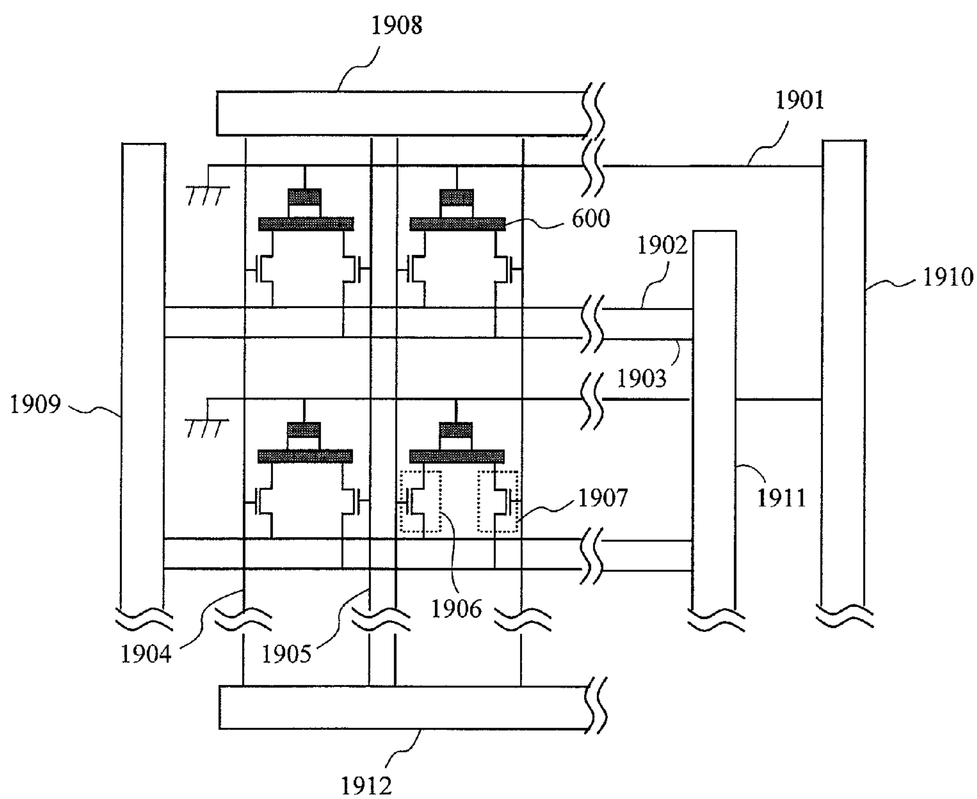

610
604
605
606
608
607
600
602
601
609
1801

FIG. 19


1908
1901
600
1902
1910
1903
1909
1907
1911
1906
1904
1905
1912

MAGNETORESISTANCE EFFECT ELEMENT AND MAGNETIC MEMORY

TECHNICAL FIELD

The present invention relates to a magnetoresistance effect element and a magnetic memory (MRAM: Magnetic Random Access Memory) provided with the magnetoresistance effect element as a memory cell. Particularly, the present invention relates to a MRAM in which a magnetic domain wall motion system is adopted for write operation.

BACKGROUND

A MRAM is a nonvolatile memory that is considered a promising candidate for a universal memory from the viewpoint of high integration and high operating speed, for example. In a memory cell of a MRAM, a magnetoresistance effect element, such as a GMR (giant magnetoresistance) element or a TMR (tunnel magnetoresistance) element, is used as a storage element. These elements have a three-layer structure as a basic structure such that a non-magnetic layer is sandwiched between two ferromagnetic layers, i.e., a first ferromagnetic layer and a second ferromagnetic layer. One of the two ferromagnetic layers is a pinned layer with a fixed direction of magnetization, while the other is a recording layer with a switchable direction of magnetization. In the following, an example is described in which the first ferromagnetic layer is the pinned layer and the second ferromagnetic layer is the recording layer. The element has a low resistance when the magnetization direction of the pinned layer and the magnetization direction of the recording layer are parallel to each other (P state), or a high resistance when the magnetization directions are antiparallel (AP state). The ratio of such changes in resistance exceeds 600% at room temperature in the case of a TMR element in which MgO is used for the non-magnetic layer, as described in Non-patent Document 1, for example. The resistance ratio is known to be particularly high in the case involving coherent tunneling conduction via the Δ_1 band, which is realized in a combination of a ferromagnetic material that contains at least one 3d transition metal element, such as Co or Fe, and MgO. In the MRAM, the resistance change is associated with bit information of "0" and "1". As a method for writing bit information, a magnetization switching system based on spin injection has been proposed, as described in Non-patent Document 2. This system utilizes the phenomenon in which magnetization direction is changed by spin-transfer torque produced by a current caused to flow through the magnetoresistance effect element. When the current is caused to flow from the pinned layer to the recording layer, the magnetizations of the pinned layer and the recording layer become antiparallel, and the bit information is "1". On the other hand, when current is caused to flow from the recording layer to the pinned layer, the magnetizations of the pinned layer and the recording layer are parallel, and the bit information is "0".

However, in this system, a large current needs to flow through the magnetoresistance effect element itself at the time of writing. Thus, in the case of the TMR element with an insulator for the non-magnetic layer, the withstand voltage of an insulating layer becomes an issue. Further, as the reading speed is increased, higher magnetoresistance ratio values are required; generally, a high magnetoresistance ratio of 70% to 100% or higher is required. In the case of a GMR element in which an insulating layer is not used in the non-magnetic layer, there is the problem of long read time because of the small resistance ratio.

Patent Document 1, for example, discloses a MRAM of the magnetic domain wall motion type in which magnetic domain wall motion by a spin transfer effect is utilized. A magnetic domain wall is a region with a finite volume at the boundary of a plurality of regions called "magnetic domains" in which magnetization directions are aligned in a ferromagnet. Particularly, when the magnetization directions of two magnetic domains adjacent to each other are antiparallel, the magnetic domain wall at their boundary is referred to as a 180° magnetic domain wall. The magnetoresistance effect element of a memory cell of the magnetic domain wall motion type MRAM described in Patent Document 1 is provided with a pinned layer with fixed magnetization; a non-magnetic layer stacked on the pinned layer; and a magnetic recording layer stacked on the non-magnetic layer.

FIG. **1** shows a basic structure of a magnetoresistance effect element **100** of a memory cell of the magnetic domain wall motion type MRAM described in Patent Document 1, for example. FIG. **1**(*a*) is a plan view, and FIG. **1**(*b*) is a cross-sectional view. The magnetoresistance effect element **100** is provided with a pinned layer **101** which is a ferromagnet with fixed magnetization; a non-magnetic layer **102** stacked on the pinned layer; and a ferromagnetic magnetic recording layer **103** stacked on the non-magnetic layer. The magnetic recording layer **103** has a thin wire shape. Specifically, the magnetic recording layer **103** includes a magnetization switching region **104** with a region in which a magnetic domain wall with a finite width can move, the region disposed at a portion overlapping with the pinned layer **101** and the non-magnetic layer **102**; and a pair of pinned magnetization regions **105** and **106** formed adjacent to the magnetization switching region **104**. The pinned magnetization regions **105** and **106** are provided with pinned magnetization of opposite directions.

To the pinned magnetization regions **105** and **106**, current supply terminals **107** and **108**, respectively, are joined. To the pinned layer **101**, a current supply terminal **107** is joined. At the time of writing, a write current is passed, via the current supply terminals **107** and **108**, through the magnetization switching region **104** and the pinned magnetization regions **105** and **106** of the magnetic recording layer **103**. In the magnetization switching region **104**, a magnetic domain wall **110** is introduced. The magnetization switching region **104** have magnetization directions antiparallel to each other, with the magnetic domain wall **110** providing a boundary. When the write current flows, the magnetic domain wall **110** is moved such that the magnetization direction is changed in a region of the magnetization switching region **104** immediately above the pinned layer **101** and the non-magnetic layer **102**. In the example of FIG. **1**, when the current is passed from the current supply terminal **107** to the current supply terminal **108**, the magnetic domain wall **110** is moved toward the pinned magnetization layer **105** such that the magnetization direction of the region of the magnetization switching region **104** immediately above the pinned layer **101** and the non-magnetic layer **102** becomes parallel to the magnetization of the pinned layer. When the current is passed from the current supply terminal **108** to the current supply terminal **107**, the magnetic domain wall **110** is moved toward the pinned magnetization layer **106** such that the magnetization direction of the region of the magnetization switching region **104** immediately above the pinned layer **101** and the non-magnetic layer **102** becomes antiparallel to the magnetization of the pinned layer.

This system is advantageous in that, because no current flows through the non-magnetic layer **102** at the time of writing, the withstand voltage of an insulator does not need to be considered even when an insulator represented by MgO is used for the non-magnetic layer, so that a highly reliable structure can be obtained. At the time of reading, a read current smaller than the write current such that the magnetic domain wall **110** is not moved is passed through the pinned layer **101**, the non-magnetic layer **102**, and the magnetic recording layer **103** via the current supply terminal **107** and the current supply terminal **109**, or the current supply terminal **108** and the current supply terminal **109**. As a result, a current path structure similar to that of a GMR or a TMR is established, and the resistance change can be read as bit information.

RELATED ART DOCUMENTS

Patent Document

Patent Document 1: Japanese Unexamined Patent Publication No. 2009-099625

Non-Patent Documents

Non-patent Document 1: S. Ikeda, J. Hayakawa, Y. Ashizawa, Y. M. Lee, K. Miura, H. Hasegawa, M. Tsunoda, F. Matsukura, H. Ohno, Appl. Phys. Lett., 93, 082508 (2008)

Non-patent Document 2: J. C. Slonczewski, J. Magn. Magn. Mater., 159, L1-L7 (1996)

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

In the MRAM utilizing magnetic domain wall motion, the absolute value of write current may possibly become relatively large. While a number of observations of magnetic domain wall motion have been reported besides Non-patent Document 2, magnetic domain wall motion generally requires a threshold current density of around 1×10^8 A/cm^2. In this case, the write current would be 1 mA even when the width of the magnetic recording layer in which magnetic domain wall motion occurs is 100 nm and the film thickness is 10 nm, for example.

On the other hand, in a magnetoresistance effect element in which a perpendicular magnetic anisotropy material with magnetic anisotropy perpendicular to a substrate plane is used for the pinned layer and the magnetic recording layer, a threshold current density on the order of 10^6 A/cm^2 has been observed (see S. Mangin, D. Ravelosona, J. A. Katine, M. J. Carey, B. D. Terris and Eric E. Fullerton, Nature Mater., 5, 210 (2006), for example). In the MRAM utilizing magnetic domain wall motion, it is expected that the write current can be decreased by using a perpendicular magnetic anisotropy material for the magnetic recording layer. The perpendicular magnetic anisotropy material, because of its high thermal stability, provides the advantage of long retention time due to stabilized position of the magnetic domain wall. However, when a conventional perpendicular magnetic anisotropy material, such as FePt, a CoFe/Pd multilayer film, and TbFeCo, is used for the pinned layer and the magnetic recording layer **103**, the resistance ratio is small because the coherent tunneling conduction via the Δ_1 band does not occur even in a TMR structure using MgO for the non-magnetic layer. As a result, the bit information reading speed is lowered, since a high-speed read operation is generally considered to require a resistance ratio of 70% or more. Further, these materials are known to have a large damping constant α. Thus, the speed of movement of the magnetic domain wall may be decreased, with a resultant decrease in write speed.

An object of the present invention is to provide a magnetoresistance effect element in which bit information is written into a magnetic recording layer by magnetic domain wall motion, including a magnetic recording layer with perpendicular magnetic anisotropy, a large resistance ratio, and high speed of magnetic domain wall motion, and a magnetic random access memory.

Solutions to the Problems

In order to solve the problems, the magnetoresistance ratio is controlled by using a material including at least one type of 3d transition metal such as Co or Fe, or a Heusler alloy which is a half metal represented by Co_2MnSi and the like with spin polarizability of 100%, as the material of at least one of a pinned layer and a magnetic recording layer of a magnetoresistance effect element of magnetic domain wall motion type. Normally, when a magnetoresistance effect element is made from a material including at least one type of 3d transition metal, such as Co or Fe, that enables coherent tunneling conduction by the Δ_1 band, or a Heusler alloy, the magnetization direction of the ferromagnetic layers is oriented parallel to film plane. However, the present inventors have developed a technology for achieving low threshold current density and high thermal stability factor by controlling the film thickness of the ferromagnetic layers on an atomic layer level such that the magnetization direction becomes perpendicular to film plane.

FIG. **2** shows the film thickness necessary for magnetization direction to become perpendicular to film plane versus the temperature of an annealing process included in a manufacturing process, in an example in which CoFeB is used for the ferromagnetic layers. CoFeB is one of materials that enable coherent tunneling conduction by the Δ_1 band in a combination with MgO. In the example, annealing was performed for one hour. The white dots in the figure indicate upper limits of the film thickness, while the black dots indicate lower limits of the film thickness. As shown, the range of film thickness of CoFeB in which the magnetization direction becomes perpendicular to film plane varies in accordance with the annealing temperature.

The example of FIG. **2** is for CoFeB, and the relationship between the film thickness necessary for the magnetization direction to become perpendicular to film plane and the annealing temperature may differ from the example of FIG. **2** for a material including at least one type of other 3d transition metal, or a Heusler alloy. However, the magnetization direction can be changed from parallel to perpendicular to film plane by appropriately controlling the film thickness for the particular material. The film thickness necessary for the magnetization direction to become perpendicular to film plane may vary from one material to another but is generally 3 nm or less. The cause of the magnetization direction becoming perpendicular to film plane is thought to involve a specific change in anisotropy at the interface of CoFeB in the case of the example of FIG. **2**. By making a thin film by controlling the film thickness of CoFeB on an atomic layer level, the ratio of the volume in which the interfacial effect is present to the volume of the CoFeB layer can be increased. As a result, the specific anisotropy effect at the interface is markedly exhibited, causing the magnetization direction to become perpendicular to film plane. It is thought that the effect is particularly pronounced at the interface between an oxygen-containing compound represented by MgO, Al_2O_3, SiO_2, and the like, and a ferromagnetic material including at least one type of 3d transition metal, such as Co or Fe, thereby causing the magnetization to be more easily oriented perpendicularly to film plane.

FIG. **3** shows the magnetoresistance ratio of the magnetoresistance effect element measured when a read current was passed through the pinned layer, the non-magnetic layer, and the magnetic recording layer, versus the annealing temperature in an example in which CoFeB was used for the pinned layer and the magnetic recording layer and MgO was used for the non-magnetic layer. As the annealing temperature is increased, the magnetoresistance ratio increases and exceeds 100% at 300° C. This is because, in the combination of CoFeB and MgO, coherent tunneling conduction via the Δ_1 band occurs even when the anisotropy is changed to a perpendicular direction. Thus, in this example, annealing may be performed at approximately 250° C. for obtaining a magnetoresistance ratio of 70%, or at 300° C. for obtaining a magnetoresistance ratio of 100%. Thus, in order to obtain the magnetoresistance effect element with magnetization direction perpendicular to film plane when the annealing temperature is 300° C., the film thickness of the pinned layer and the magnetic recording layer may be controlled to be on the order of 1.0 nm to 1.6 nm according to FIG. **2**.

Even when a material including at least one type of other 3d transition metal is used, the magnetoresistance effect element with a desired magnetoresistance ratio and magnetization direction perpendicular to film plane can be made by investigating the relationship between the annealing temperature and the magnetoresistance ratio in advance, as long as the coherent conduction via the Δ_1 band can be achieved. Generally, when a Heusler alloy is used, the spin polarizability is originally 100%, so that the magnetoresistance effect element with a high magnetoresistance ratio and magnetization direction perpendicular to film plane can be made.

FIG. **4** shows changes in resistance of the magnetoresistance effect element versus a magnetic field applied perpendicularly to film plane, in the case in which CoFeB was used for the pinned layer and the magnetic recording layer and MgO was used for the non-magnetic layer. The peaks on the plus side of magnetic field values in FIG. **4** are the peaks that appear when the magnetic field is swept from the minus direction to the plus direction. The peaks on the minus side of magnetic field values are the peaks that appear when the magnetic field is swept from the plus direction to the minus direction. In the illustrated example, the annealing temperature was 300° C. It can be seen from the experimental result that the magnetization direction is perpendicular to film plane. At this time, the magnetoresistance ratio was 100%. In the magnetoresistance effect element formed from these materials, no decrease in read speed is caused, and high thermal stability and long retention time can be obtained due to perpendicular magnetic anisotropy.

FIG. **5** shows the CoFeB film thickness dependency of the damping constant α of CoFeB. As seen from the figure, the damping constant α of a range such that the anisotropy is perpendicular to film plane is smaller than the damping constant α of conventionally known perpendicular anisotropy material, which is on the order of 0.1. Thus, the decrease in speed of movement of the magnetic domain wall can be suppressed, and a sufficiently high write speed can be achieved. Similar advantages can be obtained when a Heusler alloy is used because of its sufficiently small damping constant α, as described by M. Oogane, T. Wakita, S. Yakata, R. Yilgin, Y. Ando, A. Sakuma, and T. Miyazaki in Jpn. J. Appl. Phys., 45, 3889 (2006).

Effects of the Invention

By applying the present invention, a magnetoresistance effect element of a magnetic domain wall motion type MRAM that has a large magnetoresistance ratio and a perpendicular magnetization direction with respect to film plane can be easily made. When the magnetoresistance ratio is desired to be controlled, the annealing temperature may be controlled, and the magnetoresistance effect element can be made in which the perpendicular magnetization direction with respect to film plane is maintained by adjusting the film thickness of the pinned layer and the magnetic recording layer formed with the non-magnetic layer sandwiched therebetween. Further, by applying the present invention, magnetic anisotropy can be easily controlled by controlling the film thickness of the pinned layer and the magnetic recording layer. Further, a high magnetoresistance ratio and low damping constant α can be obtained, so that high-speed read and write operations can be performed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**(*a*) is a plan view of a magnetoresistance effect element used as a recording element in a memory cell of a magnetic domain wall motion type MRAM, and FIG. **1**(*b*) is a cross-sectional view of the magnetoresistance effect element.

FIG. **2** shows changes in film thickness necessary for the magnetization direction of the magnetoresistance effect element to become perpendicular to film plane versus the annealing process temperature in a case in which CoFeB is used for a pinned layer and a magnetic recording layer.

FIG. **3** shows changes in the magnetoresistance ratio of the magnetoresistance effect element versus the annealing process temperature in the case in which CoFeB is used for the pinned layer and the magnetic recording layer.

FIG. **4** shows changes in resistance of the magnetoresistance effect element versus the application of a magnetic field perpendicularly to film plane in the case in which CoFeB is used for the pinned layer and the magnetic recording layer.

FIG. **5** shows the damping factor α versus the film thickness of CoFeB in the case in which CoFeB is used for the pinned layer and the magnetic recording layer.

FIG. **6** includes a schematic plan view and a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **7** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **8** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **9** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **10** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **11** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **12** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **13** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **14** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **15** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **16** includes a schematic plan view and a schematic cross sectional view of the magnetoresistance effect element according to the present invention.

FIG. **17** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **18** is a schematic cross sectional view of an example of the magnetoresistance effect element according to the present invention.

FIG. **19** is a conceptual diagram of an example of a magnetic domain wall motion type MRAM according to the present invention.

MODE FOR CARRYING OUT THE INVENTION

In the following, a magnetic domain wall motion type MRAM according to the present invention and a magnetoresistance effect element used in a memory cell of the magnetic domain wall motion type MRAM as a recording element will be described in detail with reference to the drawings.

First Embodiment

FIG. **6** schematically shows an example of the magnetoresistance effect element according to the present invention, (a) being a schematic plan view and (b) being a schematic cross sectional view.

According to an aspect of the present invention, a magnetoresistance effect element **600**, as shown in FIG. **6**, is provided with a pinned layer **601** which is a ferromagnet with fixed magnetization; a non-magnetic layer **602** stacked on the pinned layer; and a ferromagnetic magnetic recording layer **603** stacked on the non-magnetic layer **602**. The non-magnetic layer **602** and the magnetic recording layer **603** have a thin wire shape. The material of the pinned layer **601** and the magnetic recording layer **603** is preferably a ferromagnetic material including at least one type of 3d transition metal element, such as Co or Fe, or a Heusler alloy represented by Co_2MnSi and the like. The material of the non-magnetic layer **602** is preferably a material such that the magnetoresistance ratio can be increased; candidates are an oxygen-containing compound such as MgO, Al_2O_3, SiO_2, and the like, and a metal such as Cu. In the present example, the material of the pinned layer **601** and the magnetic recording layer **603** is CoFeB, while the material of the non-magnetic layer **602** is MgO.

As shown in FIG. **2**, by controlling the film thickness of the pinned layer **601** and the magnetic recording layer **603** to be on the order of 1.0 nm to 1.6 nm, the magnetizations of the pinned layer **601** and the magnetic recording layer **603** can be made perpendicular to film plane at the annealing temperature of 300° C. In this case, the magnetoresistance ratio of 100% or more can be achieved, as shown in FIG. **3**. In the example of FIG. **6**, the pinned layer **601** has a circular planar shape measuring 40 nm in diameter. As the planar shape for the pinned layer **601**, a square, rectangular, or elliptical shape may be considered. Preferably, however, a circular shape with no magnetic anisotropy in a direction parallel to film plane is employed. The thin wire of the magnetic recording layer **603** has a wire width of 40 nm. The magnetization switching region **604** has a thin wire length of 150 nm. This is so that the magnetic domain wall **610** can be moved in a range wider than a region immediately above the pinned layer **601** and the non-magnetic layer **602** because, if the magnetic domain wall **610** stops in the region immediately above the pinned layer **601** and the non-magnetic layer **602**, bit information may not be accurately read at the time of reading. Thus, the condition needs to be satisfied that the length of the thin wire of the magnetization switching region **604** be greater than {(diameter of pinned layer **601**)+2×(width of magnetic domain wall)}. The pinned magnetization regions **605** and **606** have a thin wire length of 150 nm. The pinned magnetization regions **605** and **606** are provided with magnetizations which are mutually oppositely oriented and strongly fixed. This ensures that the magnetization is switched at least once in the magnetization switching region **604**. Accordingly, in the magnetization switching region **604**, one or more 180° magnetic domain walls exist without fail.

To the pinned magnetization regions **605** and **606**, current supply terminals **607** and **608**, respectively, are joined. Via the current supply terminals **607** and **608**, a write current flows through the magnetization switching region **604** and the pinned magnetization regions **605** and **606** of the magnetic recording layer **603**. When there are two or more magnetic domain walls in the magnetization switching region **604**, a write current may be passed through the magnetization switching region **604** and the pinned magnetization regions **605** and **606** so as to move the plurality of magnetic domain walls to one end of the magnetization switching region **604**, so that the plurality of magnetic domain walls can be eliminated and only one magnetic domain wall exists in the magnetization switching region **604** without fail. By this method, only one magnetic domain wall **610** can be introduced into the magnetization switching region **604**. The non-magnetic layer **602** is designed with the same width and length as those of the magnetic recording layer **603**.

With regard to writing in the example of FIG. **6**, when a current is passed from the current supply terminal **607** to the current supply terminal **608**, the magnetic domain wall **610** is moved toward the pinned magnetization layer **605** such that the magnetization direction of the region of the magnetization switching region **604** immediately above the pinned layer **601** and the non-magnetic layer **602** becomes parallel to the magnetization of the pinned layer. When the current is passed from the current supply terminal **608** to the current supply terminal **607**, the magnetic domain wall **610** is moved toward the pinned magnetization layer **606** such that the magnetization direction of the region of the magnetization switching region **604** immediately above the pinned layer **601** and the non-magnetic layer **602** becomes antiparallel to the pinned layer.

With regard to reading, a read current smaller than the write current such that the magnetic domain wall **610** is not moved is passed through the pinned layer **601**, the non-magnetic layer **602**, and the magnetic recording layer **603** via the current supply terminal **607** and the current supply terminal **609**, or via the current supply terminal **608** and the current supply terminal **609**. In this way, a current path structure similar to that of a GMR or a TMR is established, so that the resistance change can be read as bit information.

In the example of FIG. **6**, the pinned layer **601**, the non-magnetic layer **602**, and the magnetic recording layer **603** are successively stacked in this order. Preferably, the layers may be stacked in the order of the magnetic recording layer **603**, the non-magnetic layer **602**, and the pinned layer **601**, as shown in the schematic cross sectional view of FIG. **7**. Further, in the example of FIG. **6**, the pinned layer **601** has downward magnetization, the pinned magnetization region **605** has upward magnetization, and the pinned magnetization region **606** has downward magnetization. However, the magnetization directions are not particularly limited and the magnetization directions may be fixed in such a way that the manufacture can be facilitated, as long as the magnetization directions of the pinned magnetization region **605** and the pinned magnetization region **606** are antiparallel to each other.

The material of the pinned layer **601** may be a conventionally known perpendicular magnetic anisotropy material, such as FePt, and the material of the magnetic recording layer **603** may be CoFeB. In this case, the magnetoresistance ratio may be decreased because coherent tunneling conduction via the Δ_1 band cannot be achieved in the conventionally known perpendicular magnetic anisotropy material such as FePt; however, write and read operations can be performed. This configuration is advantageous in that the magnetic anisotropy of the pinned layer **601** can be controlled to be large compared with the magnetic recording layer **603**. Further, the material of the pinned layer **601** may be CoFeB, and the material of the magnetic recording layer **603** may be a conventionally known perpendicular magnetic anisotropy material, such as FePt. In this configuration, too, write and read operations can be performed.

On the other hand, when the Heusler alloy Co_2MnSi is used for the pinned layer **601** and the magnetic recording layer **603**, the resistance ratio on the order of 70% can be obtained due to high spin polarizability. This value is smaller than the value in the case in which CoFeB is used for the pinned layer **601** and the magnetic recording layer **603**. This is because, when Co_2MnSi is used, coherent conduction via the Δ_1 band is not markedly exhibited. However, a resistance ratio necessary for reading can be obtained. Because of the advantage of low damping constant, the speed of movement of the magnetic domain wall is higher than in the case in which CoFeB is used for the pinned layer **601** and the magnetic recording layer **603**, so that a high-speed write operation can be performed.

According to another aspect of the present invention, the film thickness of the pinned magnetization regions **605** and **606** may be changed from the film thickness of the magnetization switching region **604** so as to strongly fix the magnetizations of the pinned magnetization regions **605** and **606**. FIG. **8** is a cross-sectional view of an example in which the film thickness of the pinned magnetization regions **605** and **606** is decreased compared with the film thickness of the magnetization switching region **604**. In the case of the material including at least one type of 3d transition metal, such as Co or Fe, or a Heusler alloy represented by Co_2MnSi or the like, as applied for the pinned layer **601** and the magnetic recording layer **603** according to the present invention, magnetization direction can be changed from parallel to perpendicular to film plane by controlling the film thickness. Further, perpendicular magnetic anisotropy can also be easily controlled by changing the film thickness.

In the example of FIG. **8**, the perpendicular magnetic anisotropy of the pinned magnetization regions **605** and **606** is controlled to be larger than the perpendicular magnetic anisotropy of the magnetization switching region **604** such that the magnetization directions of the pinned magnetization regions **605** and **606** are strongly fixed. Thus, the magnetic domain wall **610** can be easily caused to remain in the magnetization switching region **604** without entering the pinned magnetization regions **605** and **606**. Further, in the example of FIG. **8**, the film thickness of the pinned magnetization regions **605** and **606** is controlled to be smaller than the film thickness of the magnetization switching region **604**. In this case, as seen from FIG. **5**, the damping constant α of the pinned magnetization regions **605** and **606** is larger than that of the magnetization switching region **604**. Thus, the speed of magnetic domain wall motion in the pinned magnetization regions **605** and **606** is smaller than in the magnetization switching region **604**. Accordingly, even if the magnetic domain wall **610** enters the pinned magnetization region **605** or **606**, the magnetic domain wall **610** can be easily stopped around the interface between the magnetization switching region **604** and the pinned magnetization region **605** or **606** due to the low speed of movement of the magnetic domain wall **610**.

In the example of FIG. **8**, the film thickness of the pinned layer **601** and the magnetization switching region **604** is 1.3 nm, and the film thickness of the pinned magnetization regions **605** and **606** is 1.0 nm. The planar shape of the pinned layer **601** is circular measuring 40 nm in diameter. The thin wire of the magnetic recording layer **603** has the wire width of 40 nm. The magnetization switching region **604** has the thin wire length of 150 nm. The pinned magnetization regions **605** and **606** have the thin wire length of 150 nm.

According to another aspect of the present invention, for the magnetization switching region **604** of the magnetic recording layer **603**, a material including at least one type of 3d transition metal such as Co or Fe, or a Heusler alloy represented by Co_2MnSi and the like may be applied, and for the pinned magnetization regions **605** and **606**, another conventionally known perpendicular magnetic anisotropy material, such as a multilayer film of Co and Pt, Ni and Pt, and the like, or an FePt or TbFeCo alloy, may be applied. FIG. **9** is a schematic cross sectional view of the magnetoresistance effect element **600** according to this aspect. By adopting this configuration, the perpendicular magnetic anisotropy of the pinned magnetization regions **605** and **606** can be made larger than the perpendicular magnetic anisotropy of the magnetization switching region **604** when the perpendicular magnetic anisotropy of the other conventionally known perpendicular magnetic anisotropy material such as the multilayer film of Co and Pt, Ni and Pt, and the like or the FePt or TbFeCo alloy is larger than the perpendicular magnetic anisotropy of the material including at least one type of 3d transition metal such as Co or Fe or the Heusler alloy represented by Co_2MnSi and the like. In the example of FIG. **9**, FePt is used as the material of the pinned magnetization regions **605** and **606**, with the film thickness of 10 nm. The pinned layer **601** has a circular planar shape measuring 40 nm in diameter. The thin wire of the magnetic recording layer **603** has the wire width of 40 nm. The magnetization switching region **604** has the thin wire length of 150 nm. The pinned magnetization regions **605** and **606** have the thin wire length of 150 nm.

According to another aspect of the present invention, ferromagnetic layers **1001** and **1002** may be formed on the interface of the pinned magnetization regions **605** and **606** of the magnetic recording layer **603** on the side opposite to the non-magnetic layer **602**, in which another conventionally known perpendicular magnetic anisotropy material such as a multilayer film of Co and Pt, Ni and Pt, and the like, or an FePt or TbFeCo alloy is applied. FIG. **10** is a schematic cross sectional view of the magnetoresistance effect element **600** according to this aspect. By adopting this configuration, the perpendicular magnetic anisotropy of the pinned magnetization regions **605** and **606** can be increased because of ferromagnetic coupling of the perpendicular magnetic anisotropy of the pinned magnetization regions **605** and **606** with the ferromagnetic layers **1001** and **1002**. While in the example of FIG. **10** the ferromagnetic layers **1001** and **1002** are formed over the pinned magnetization regions **605** and **606**, the magnetic recording layer **603**, the non-magnetic layer **602**, and the pinned layer **601** may be successively stacked over the ferromagnetic layers **1001** and **1002** in this order, as shown in

FIG. **11**. Further, while in the examples of FIGS. **10** and **11** the current supply terminals **607** and **608** are connected to the pinned magnetization regions **605** and **606**, the terminals may be connected to the ferromagnetic layers **1001** and **1002**. In the examples of FIGS. **10** and **11**, FePt is used as the material of the ferromagnetic layers **1001** and **1002**, with the film thickness of 20 nm. The pinned layer **601** has a circular planar shape, with the diameter of 40 nm. The thin wire of the magnetic recording layer **603** has the wire width of 40 nm. The magnetization switching region **604** has the thin wire length of 150 nm. The pinned magnetization regions **605** and **606** have the thin wire length of 150 nm. A second ferromagnetic layer of a material with a larger damping constant than that of the pinned magnetization regions may be provided on the interface of the pinned magnetization regions on the side opposite to the non-magnetic layer. By the presence of the adjoining second ferromagnetic layer, the damping constant of the pinned magnetization regions can be increased.

According to another aspect of the present invention, second non-magnetic layers **1201** and **1202** in which an oxide such as MgO, Al_2O_3, SiO_2, and the like is applied may be formed on the interface of the pinned magnetization regions **605** and **606** of the magnetic recording layer **603** on the side opposite to the non-magnetic layer **602**. FIG. **12** is a schematic cross sectional view of the magnetoresistance effect element **600** according to this aspect. The magnetic anisotropy of the material including at least one type of 3d transition metal such as Co or Fe, or a Heusler alloy represented by Co_2MnSi and the like can be changed from parallel to perpendicular with respect to film plane by controlling their film thickness because of the specific anisotropy at the interface. This specific interfacial anisotropy is thought to be particularly exhibited at the interface with an oxide, such as MgO, Al_2O_3, and SiO_2. Thus, by adopting this configuration, the perpendicular magnetic anisotropy of the pinned magnetization regions **605** and **606** can be increased. The film thickness is 0.4 nm in the case in which MgO is used for the second non-magnetic layers **1201** and **1202**, for example. In the second non-magnetic layers **1201** and **1202**, a material with large spin orbit interaction represented by Pt and Pd may be applied. By adopting this configuration, the damping constant of the pinned magnetization regions **605** and **606** can be increased over the values shown in FIG. **5**. As the damping constant is increased, the speed of movement of the magnetic domain wall **610** is sharply decreased as the magnetic domain wall **610** enters the pinned magnetization region **605** or **606**. Thus, the magnetic domain wall **610** can be stopped at the boundary between the magnetization switching region **604** and the pinned magnetization region **605** or **606**. The film thickness is 2 nm when Pt is used for the second non-magnetic layer, for example. The pinned layer **601** has a circular planar shape measuring 40 nm in diameter. The thin wire of the magnetic recording layer **603** has the wire width of 40 nm. The magnetization switching region **604** has the thin wire length of 150 nm. The pinned magnetization regions **605** and **606** have the thin wire length of 150 nm.

In the example of FIG. **12**, the second non-magnetic layers **1201** and **1202** are formed over the pinned magnetization regions **605** and **606**. Preferably, the magnetic recording layer **603**, the non-magnetic layer **602**, and the pinned layer **601** may be successively stacked over the second non-magnetic layers **1201** and **1202** in this order, as shown in FIG. **13**. While in the examples of FIGS. **12** and **13** the current supply terminals **607** and **608** are connected to the pinned magnetization regions **605** and **606**, the terminals may be connected to the pinned magnetization regions **605** and **606** via the second non-magnetic layers **1201** and **1202**.

According to another aspect of the present invention, antiferromagnetic layers **1401** and **1402** may be formed on the interface of the pinned magnetization regions **605** and **606** of the magnetic recording layer **603** on the side opposite to the non-magnetic layer **602**. FIG. **14** is a schematic cross sectional view of the magnetoresistance effect element **600** according to this aspect. By adopting this configuration, the magnetizations of the pinned magnetization regions **605** and **606** can be strongly fixed because of exchange coupling with the antiferromagnetic layers **1401** and **1402**. The film thickness is 5 nm when IrMn is used for the antiferromagnetic layers **1401** and **1402**, for example. The pinned layer **601** has a circular planar shape measuring 40 nm in diameter. The thin wire of the magnetic recording layer **603** has the wire width of 40 nm. The magnetization switching region **604** has the thin wire length of 150 nm. The pinned magnetization regions **605** and **606** have the thin wire length of 150 nm.

In the example of FIG. **14** the antiferromagnetic layers **1401** and **1402** are formed over the pinned magnetization regions **605** and **606**. Preferably, the magnetic recording layer **603**, the non-magnetic layer **602**, and the pinned layer **601** may be stacked successively in this order over the antiferromagnetic layers **1401** and **1402**, as shown in FIG. **15**. While in the examples of FIGS. **14** and **15** the current supply terminals **607** and **608** are connected to the pinned magnetization regions **605** and **606**, the terminals may be connected to the pinned magnetization regions **605** and **606** via the antiferromagnetic layers **1401** and **1402**.

According to another aspect of the present invention, a structure may be adopted such that the magnetic recording layer **603** has constrictions at the boundary of the magnetization switching region **604** and the pinned magnetization regions **605** and **606**. FIG. **16** shows the magnetoresistance effect element **600** according to this aspect. FIG. **16**(*a*) is a schematic plan view, while FIG. **16**(*b*) is a schematic cross sectional view. By applying this configuration, the magnetic domain wall **610** is strongly pinned by the constrictions such that the magnetic domain wall **610** does not enter the pinned magnetization regions **605** and **606**. In the example of FIG. **16**, the film thickness of the pinned layer **601** and the magnetic recording layer is 1.3 nm, while the film thickness at the constriction portions is 1.0 nm. The pinned layer **601** has a circular planar shape measuring 40 nm in diameter. The thin wire of the magnetic recording layer **603** has the wire width of 40 nm. The magnetization switching region **604** has the thin wire length of 150 nm. The constriction portions have the wire width of 38 nm.

According to another aspect of the present invention, the magnetoresistance effect element **600** may be configured such that the non-magnetic layer **602** adjoins only the magnetization switching region **604** of the magnetic recording layer **603**. FIG. **17** shows the magnetoresistance effect element **600** according to this aspect. In this case, the non-magnetic layer **602** adjoins neither the pinned magnetization region **605** nor **606**. The anisotropy of the material including at least one type of 3d transition metal such as Co or Fe, or the Heusler alloy represented by Co_2MnSi and the like, can be changed from parallel to perpendicular with respect to film plane by controlling their film thickness, supposedly because of specific interfacial anisotropy. This specific anisotropy is particularly exhibited at the interface between such ferromagnets and an oxide represented by MgO. Thus, according to the present embodiment, the magnetoresistance effect element **600** has perpendicular magnetic anisotropy only in the magnetization switching region **604**, with the pinned magnetization regions **605** and **606** having in-plane magnetic anisotropy. By adopting this configuration, a 90° magnetic domain wall is introduced between the pinned magnetization regions **605** and **606** and the magnetization switching region **604**. When the magnetic domain wall **610** in the magnetization switching region **604** is present at the end of the magnetization switching region **604**, the electron spins that provide spin-transfer torque to the magnetization of the magnetization switching region **604** are inclined by 90°, possibly resulting in an increase in the torque and a decrease in write current. In the case of this configuration, too, the magnetic domain wall **610** is stopped within the magnetization switching region **604** and does not enter the pinned magnetization region **605** or **606**.

Second Embodiment

According to another aspect of the present invention, the magnetoresistance effect element **600** according to the first embodiment may include a pinned magnetization layer **1801** formed on the interface of the pinned layer **601** on the side opposite to the non-magnetic layer **602** by stacking another conventionally known perpendicular magnetic anisotropy material, such as a multilayer film of Co and Pt, Ni and Pt, and the like, or an FePt or TbFeCo alloy, so as to increase and strongly fix the perpendicular magnetic anisotropy of the pinned layer **610**. FIG. **18** shows the magnetoresistance effect element **600** according to this aspect. By adopting this configuration, the perpendicular magnetic anisotropy of the pinned layer **601** can be increased by the ferromagnetic coupling with the perpendicular magnetic anisotropy material. The film thickness is 20 nm when FePt is used for the pinned magnetization layer **1801**, for example. For the same purpose, an antiferromagnetic layer may be stacked on the interface of the pinned layer **601** on the side opposite to the non-magnetic layer **602**. In this case, the perpendicular magnetic anisotropy of the pinned layer **601** is increased by its exchange coupling with the antiferromagnetic layer. The film thickness is 5 nm when IrMn is used for the pinned magnetization layer **1801**, for example. Further, an oxide layer of MgO, Al_2O_3, SiO_2, and the like may be stacked on the interface of the pinned layer **601** on the side opposite to the non-magnetic layer **602**. In this case, the perpendicular magnetic anisotropy is increased due to the specific anisotropy at the interface with the pinned layer **601**. The film thickness is 0.4 nm when MgO is used for the pinned magnetization layer **1801**, for example. A material with large spin orbit interaction represented by Pt and Pd may be stacked on the interface of the pinned layer **601** on the side opposite to the non-magnetic layer **602**. In this case, although the damping constant α of the pinned layer **601** is increased such that the perpendicular magnetic anisotropy is not changed, magnetization switching of the pinned layer **601** by current is made difficult to occur. Thus, the possibility of erroneously switching the magnetization of the pinned layer **601** by read current can be decreased. The film thickness is 2 nm when Pt is used for the pinned magnetization layer **1801**, for example.

Third Embodiment

According to another aspect of the present invention, a magnetic domain wall motion type MRAM can be obtained by adopting the magnetoresistance effect element **600** according to the first or the second embodiment as a storage element.

As shown in FIG. **19**, the magnetic domain wall motion type MRAM according to the present invention is provided with two selection transistors for each magnetoresistance effect element **600**, and include a plurality of bit lines **1901** disposed in parallel to each other; a plurality of first source lines **1902** disposed in parallel to the bit lines **1901** and parallel to each other; and a plurality of second source lines **1903** disposed in parallel to the bit lines **1901** and the first source lines **1902** and parallel to each other. The magnetic domain wall motion type MRAM also includes first word lines **1904** disposed perpendicularly to the bit lines **1901**, the first source lines **1902**, and the second source lines **1903** and in parallel to each other; and second word lines **1905** disposed perpendicularly to the bit lines **1901**, the first source lines **1902**, and the second source lines **1903**, in parallel to the first word lines **1904**, and in parallel to each other.

At each point of intersection of the first source lines **1902** and the first word lines **1904**, a first selection transistor **1906** is disposed. The first source lines **1902** are electrically connected to a source electrode of the first selection transistor **1906**. The first word lines **1904** are electrically connected to a gate electrode of the first selection transistor **1906**. A drain electrode of the first selection transistor **1906** is electrically connected to the current supply terminal **607** of the magnetoresistance effect element **600**. At each point of intersection of the second source lines **1903** and the second word lines **1905**, a second selection transistor **1907** is disposed. The second source lines **1903** are electrically connected to a source electrode of the second selection transistor **1907**. The second word lines **1905** are electrically connected to a gate electrode of the second selection transistor **1907**. A drain electrode of the second selection transistor **1907** is electrically connected to the current supply terminal **608** of the magnetoresistance effect element **600**. The bit lines **1901** are electrically connected to the pinned layer **601** of the magnetoresistance effect element **600**. Selection circuits **1908** and **1909**, and current applying circuits **1910**, **1911**, and **1912** are also connected. By adopting this configuration, a memory cell of the magnetic domain wall motion type MRAM can be obtained.

A write operation for the memory cell will be described. When writing by selecting a particular memory cell, a voltage is applied to the first word line **1904** and the second word line **1905** while a voltage is applied to the first source line **1902** or the second source line **1903** of the selected memory cell. At this time, the first selection transistor **1906** and the second selection transistor **1907** of the selected memory cell are in an on-state, so that a current flows through the magnetoresistance effect element **600** from one of the first source line **1902** and the second source line **1903** to which the voltage was applied, to the other. At this time, because the current flows through the magnetization switching region **604** of the magnetoresistance effect element, the magnetic domain wall **610** can be moved in one direction. When writing different information, the source line to which the voltage is applied is reversed between the first source line **1902** and the second source line **1903** such that the current flows through the magnetization switching region **604** in the opposite direction, thus causing the magnetic domain wall **610** to be moved in the opposite direction. For example, when the voltage is applied to the first source line **1902**, the current flows from the first source line **1902** to the second source line **1903**. When the magnetoresistance effect element shown in FIG. **6** is adopted as the magnetoresistance effect element **600**, the electrons move from the right to left of the magnetization switching region **604** shown in FIG. **6**, so that the magnetic domain wall **610** is also moved from right to left. At this time, the direction of magnetization of the region of the magnetization switching region **604** immediately above the pinned layer **601** becomes parallel to the direction of magnetization of the pinned layer **601**, so that information in a “0” state can be written. On the other hand, a "1" state can be written by applying the voltage to the second source line **1903**. For a read operation, a voltage is applied to the first word line **1904** while a voltage smaller than that for writing is applied to the first source line **1902**. At this time, the first selection transistor **1906** is placed in an on-state and current flows from the first source line **1902** to a bit line **1901**, so that the resistance value of the magnetoresistance effect element **600** can be read. Reading may be performed by applying voltage to the second source line **1903** and the second word line **1905**.

DESCRIPTION OF REFERENCE SIGNS

100 Magnetoresistance effect element
101 Pinned layer
102 Non-magnetic layer
103 Magnetic recording layer
104 Magnetization switching region
105, **106** Pinned magnetization region
107 to **109** Current supply terminal
110 Magnetic domain wall
600 Magnetoresistance effect element
601 Pinned layer
602 Non-magnetic layer
603 Magnetic recording layer
604 Magnetization switching region
605, **606** Pinned magnetization region
607 to **609** Current supply terminal
610 Magnetic domain wall
1001, **1002** Ferromagnetic layer
1201, **1202** Second ferromagnetic layer
1401, **1402** Antimagnetic layer
1801 Pinned magnetization layer
1901 Bit line
1902 First source line
1903 Second source line
1904 First word line
1905 Second word line
1906 First selection transistor
1907 Second selection transistor
1908, **1909** Selection circuit
1910 to **1912** Current applying circuit

The invention claimed is:

1. A magnetoresistance effect element comprising:

a pinned layer of a ferromagnet with a fixed magnetization direction;

a magnetic recording layer of a ferromagnet with a thin wire shape including a region with a variable magnetization direction; and

a non-magnetic layer with a thin wire shape formed between the pinned layer and the magnetic recording layer,

wherein:

the magnetic recording layer includes three regions consisting of pinned magnetization regions at the ends and a magnetization switching region sandwiched therebetween;

the pinned layer and the pinned magnetization regions include current supply terminals; and

at least one of the pinned layer and the magnetic recording layer is formed from a ferromagnet enabling a magnetization direction to be changed from parallel to perpendicular to a film plane by controlling a film thickness to be not more than 3 nm, with a controlled magnetoresistance ratio and with the magnetization direction perpendicularly oriented with respect to the film plane by a film thickness control.

2. The magnetoresistance effect element according to claim **1**, wherein the non-magnetic layer adjoins the three regions of the magnetic recording layer.

3. The magnetoresistance effect element according to claim **1**, wherein the film thickness of the pinned magnetization regions and the magnetization switching region is controlled such that the perpendicular magnetic anisotropy of the pinned magnetization regions is greater than the perpendicular magnetic anisotropy of the magnetization switching region.

4. The magnetoresistance effect element according to claim **1**, wherein the material of the pinned magnetization regions and the magnetization switching region is selected such that the perpendicular magnetic anisotropy of the pinned magnetization regions is greater than the perpendicular magnetic anisotropy of the magnetization switching region.

5. The magnetoresistance effect element according to claim **1**, comprising a ferromagnetic layer disposed on an interface of the pinned magnetization regions on a side opposite to the non-magnetic layer, the ferromagnetic layer being formed from a material with a perpendicular magnetic anisotropy greater than the perpendicular magnetic anisotropy of the pinned magnetization regions,

wherein the magnetization of the pinned magnetization regions and the magnetization of the ferromagnetic layer are coupled by ferromagnetic coupling.

6. The magnetoresistance effect element according to claim **1**, comprising a second non-magnetic layer on an interface of the pinned magnetization regions on a side opposite to the non-magnetic layer,

wherein the perpendicular magnetic anisotropy of the pinned magnetization regions is greater than the perpendicular magnetic anisotropy of the magnetization switching region.

7. The magnetoresistance effect element according to claim **1**, comprising a second ferromagnetic layer on an interface of the pinned magnetization regions on a side opposite to the non-magnetic layer,

wherein:

the second ferromagnetic layer is of a material with a damping constant greater than the damping constant of the pinned magnetization regions; and

the damping constant of the pinned magnetization regions is increased by the second ferromagnetic layer adjoining the pinned magnetization regions.

8. The magnetoresistance effect element according to claim **1**, comprising an antiferromagnetic layer on an interface of the pinned magnetization regions on a side opposite to the non-magnetic layer,

wherein the magnetization of the pinned magnetization regions and the magnetization of the antiferromagnetic layer are coupled by exchange coupling.

9. The magnetoresistance effect element according to claim **1**, wherein:

the non-magnetic layer has the same length as the magnetization switching region and adjoins the magnetization switching region; and

the pinned magnetization regions have magnetization parallel to the film plane.

10. The magnetoresistance effect element according to claim **1**, comprising a constriction structure at a boundary between the pinned magnetization regions and the magnetization switching region.

11. The magnetoresistance effect element according to claim **1**, comprising an antiferromagnetic, ferromagnetic, or non-magnetic layer on an interface of the pinned layer on a side opposite to the non-magnetic layer for strongly fixing the magnetization of the pinned layer.

12. The magnetoresistance effect element according to claim **1**, wherein the non-magnetic layer is magnesium oxide.

13. The magnetoresistance effect element according to claim **1**, wherein:

the ferromagnet of at least one of the pinned layer and the magnetic recording layer is a ferromagnetic material including at least one type of a 3d transition metal; and

the magnetoresistance ratio is not less than 70%.

14. The magnetoresistance effect element according to claim **13**, wherein the 3d transition metal is at least one of Co and Fe.

15. The magnetoresistance effect element according to claim **1**, wherein the ferromagnet of at least one of the pinned layer and the magnetic recording layer is a ferromagnetic material with a damping constant of less than 0.1.

16. The magnetoresistance effect element according to claim **15**, wherein the ferromagnetic material with the small damping constant is a Heusler alloy.

17. The magnetoresistance effect element according to claim **1**, wherein the magnetoresistance ratio is controlled to be not less than 70%.

18. A magnetic memory comprising:

a plurality of bit lines disposed in parallel to each other;

a plurality of first source lines disposed in parallel to the bit lines and to each other;

a plurality of second source lines dispose in parallel to the bit lines and to each other;

a plurality of first word lines disposed in a direction intersecting the bit lines and in parallel to each other;

a plurality of second word lines disposed in a direction intersecting the bit lines and in parallel to each other;

a first selection transistor disposed at an intersection of the first source lines and the first word lines;

a second selection transistor disposed at an intersection of the second source lines and the second word lines; and

a magnetoresistance effect element disposed between the first selection transistor and the second selection transistor,

wherein:

the magnetoresistance effect element includes a pinned layer of a ferromagnet with a fixed magnetization direction; a magnetic recording layer of a ferromagnet with a thin wire shape including a region with a variable magnetization direction; and a non-magnetic layer with a thin wire shape formed between the pinned layer and the magnetic recording layer;

the magnetic recording layer includes three regions consisting of pinned magnetization regions at the ends and a magnetization switching region sandwiched therebetween, the pinned magnetization regions including current supply terminals;

at least one of the pinned layer and the magnetic recording layer is formed from a ferromagnet enabling a magnetization direction to be changed from parallel to perpendicular to a film plane by a film thickness control, with a magnetoresistance ratio controlled by the film thickness control and with the magnetization direction perpendicularly oriented with respect to the film plane;

the bit lines are electrically connected to the pinned layer of the magnetoresistance effect element;

one of the current supply terminals of the magnetoresistance effect element is electrically connected to a drain electrode of the first selection transistor;

another of the current supply terminals of the magnetoresistance effect element is electrically connected to a drain electrode of the second selection transistor;

the first source lines are electrically connected to a source electrode of the first selection transistor;

the second source lines are electrically connected to a source electrode of the second selection transistor;

the first word lines are electrically connected to a gate electrode of the first selection transistor; and

the second word lines are electrically connected to a gate electrode of the second selection transistor,

the magnetic memory further comprising a mechanism configured to apply a voltage to the bit lines, the first source lines, the second source lines, the first word lines, and the second word lines.

19. The magnetic memory according to claim **18**, wherein the non-magnetic layer adjoins the three regions of the magnetic recording layer.

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